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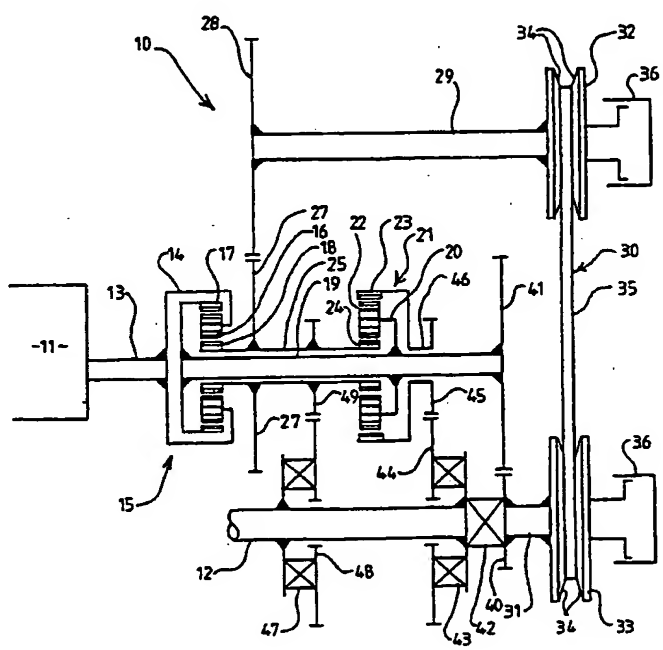
(54) Title: MULTI-STAGE, POWER SPLIT CONTINUOUSLY VARIABLE TRANSMISSION

(57) Abstract

A drive transmission (10) comprising first (15) and second (21) differential gears with a variable speed transmission (30), operatively connected between an element of the first differential gear (15) and an element of the second differential gear (21) wherein the first differential gear (15) has a first element (14) connected to a first drive member (13) of the transmission (10), a second element (17) of the first differential gear (15) is connected to a first element (20) of the second differential gear (21), a second element (23) of the second differential gear (21) is connected to a second drive member (12) of the transmission (10), a third element (18) of the first differential gear (15) is connected to a third element (24) of the second differential gear (21).



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Title: Multi-stage, power split continuously variable transmission

This invention relates to a drive transmission.

An object of the invention is to provide a new and improved drive transmission.

According to one aspect of the invention we provide a drive transmission comprising first and second differential gears with a variable speed transmission, operatively connected between an element of the first differential gear and an element of the second differential gear.

The first differential gear may have a first element connected to a first drive member of the transmission, a second element of the first differential gear being connected to a first element of the second differential gear, a second element of the second differential gear being connected to a second drive member of the transmission, a third element of the first differential gear being connected to a third element of the second differential gear.

Preferably the variable speed transmission is connected between the third element of the first differential gear and the first element of the second differential gear.

The first, second and third elements of the first differential gear may correspond to similar elements of the second differential gear.

For example, the first element of each differential gear may comprise a planet carrier, the second element of each differential gear may comprise an annulus or the functional equivalent thereof and the third element of each differential gear may comprise a sun gear or the functional equivalent thereof.

Accordingly, the sun gear of the first differential may be connected to the sun gear of the second differential whilst the annulus of the first differential is connected to the carrier of the second differential and the variable speed transmission is connected between the sun gear of the first differential and the carrier of the second differential gear.

The first differential may have a ratio, R_o of $\sqrt{\rho}$ and the second differential may have a ratio of $\rho - \geq 1$ where ρ is the ratio of the variable speed transmission.

Where the ratio R_o of the second differential $= \rho - 1$ then the second drive member of the transmission may have a zero speed of rotation whilst when the ratio of the second differential is $\rho - > 1$, the second drive member of the transmission may rotate in reverse as well as in forward direction for a constant direction of rotation of the first drive member.

By R_o we mean the ratio between the speed of the rotation of the annulus and the sun gear of the differential or their functional equivalents.

By ρ we means the product of the ratio of maximum input speed to minimum output speed and of the ratio of minimum input speed to maximum output speed. Generally these ratios are equal and in this case ρ equals the square of either ratio. For example, when the variable speed transmission is of a split pulley type, the ratio between the maximum radius and the minimum radius at which the belt engages the input and output pulley respectively equals $\sqrt{\rho}$ and the ratio between the minimum and maximum radii is also $\sqrt{\rho}$.

The second drive member of the transmission may be releasably connectable to a desired one of, the second element of the second transmission, an input element of the variable speed transmission and the output element of the variable speed transmission. The provision of such connections provides a 3-range transmission.

If less ranges are required a desired one or more of the releasable connections may be omitted.

The input element of the variable speed transmission may be releasably connectable to the second drive member of the transmission by a first mechanical gear, i.e. a gear with members that have angular velocities in a fixed proportion. The input element of the variable speed transmission may be connected to the second drive member of the transmission by said first mechanical gear through an intermediate element which interconnects the third elements of the differential.

The output element of the variable speed transmission may be releasably connectable to the second drive member of the transmission by a direct connection, i.e. without any difference in angular velocities of the members on opposite sides of the direct connection or by a further mechanical gear.

A four range transmission may be provided by providing, in addition to the releasable connections of the three range transmission, that the input element of the variable speed transmission is also releasably connectable to the second drive member of the transmission by a second mechanical gear.

The second mechanical gear may be arranged so that the members thereof have angular velocities in a different fixed proportion to the fixed proportion of the members of the first mechanical gear.

The input element of the variable speed transmission may be connectable to the second drive member by said second mechanical gear through the intermediate element.

A five range transmission may be provided by providing, in addition to the releasable connections of the four range transmission, that the input element of the variable speed transmission is also releasably connectable to the second drive member of the transmission by a third mechanical gear.

The third mechanical gear may be arranged so that the members thereof have angular velocities in a different fixed proportion to the fixed proportions of the members of the first and second mechanical gears.

The input element of the variable speed transmission may be connectable to the second drive member by said third mechanical gear through the intermediate element.

If more than five ranges are required this may be achieved by providing an appropriate number of extra releasable connections between the input element of the variable speed transmission and the second drive member of the transmission.

The above described transmissions may be provided with a reverse gear downstream of the second drive member of the transmission.

The second drive member of the transmission may be releasably connectable to a further shaft through a forward clutch or a reverse clutch, the reverse clutch having a reverse gear associated therewith.

The above mentioned releasable connections may each comprise a suitable clutch.

The transmissions are arranged so that at range change the members of a clutch to be released and of a clutch to be engaged are rotating synchronously so that both clutches may be simultaneously engaged during range change to permit of range change without interruption of torque transmitted by the transmission.

The first drive member of the transmission may be an input member and the second drive member of the transmission may be an output member.

The variable speed transmission may be a finite continuously variable transmission having a single direction of rotation of an output element compared with an input element and the ratio of the speed of rotation of the input element to the output element being finite.

The finite continuously variable transmission may be a mechanically continuously variable transmission such as a split pulley type comprising a pair of split pulleys having variable spacing cheeks, drivingly interconnected by a continuous loop and in which the radius at which the loop drivingly engages the split pulleys is continuously adjustable by varying the spacing between the cheeks of the split pulleys. Preferably the loop is a metal pusher belt.

Alternatively, the mechanical continuous variable transmission may be of the toroidal disk drive type comprising two disks, each with a toroidal working surface engageable by a roller, the axis of rotation of the roller being adjustable to vary the radial positions at which the roller engages the toroidal surfaces.

The first and second differentials may each comprise a "parallel axis epicyclic gear set" by which we mean a gear set comprising a planet carrier, acting as a first element, supporting planet gears which are rotatable about axes parallel to the axis of rotation of an annulus, acting as a second element, and in mesh with the annulus and in mesh with a sun gear, acting as a third element.

If desired, however, the differential gear sets may be of any other suitable type or combination of types.

The driven member of the transmission may be connectable to provide motive power for a vehicle and/or provide a power input to apparatus of the vehicle.

The vehicle may be a construction machine provided with an earth moving appliance.

Embodiments of the invention will now be described with reference to the accompanying drawings, wherein:

FIGURE 1 is a diagrammatic illustration of a three range drive transmission suitable for use in a car;

FIGURE 1a shows operating characteristics of the transmission of Figure 1,

FIGURE 2 is a diagrammatic illustration of a four range drive transmission suitable for use in a lorry;

FIGURE 2a shows operating characteristics of the transmission of Figure 2,

FIGURE 3 is a diagrammatic illustration of a four range drive transmission suitable for use in a back hoe type excavator;

FIGURE 3a shows operating characteristics of the transmission of Figure 3,

FIGURE 4 is a diagrammatic illustration of a five range drive transmission suitable for use in a tractor.

FIGURE 4a shows operating characteristics of the transmission of Figure 4,

FIGURE 5 is a diagrammatic illustration of another embodiment of the invention,

FIGURE 6 is a diagrammatic illustration of a still further embodiment of the invention,

FIGURE 7 is a diagrammatic side elevation of a vehicle provided with a transmission according to the invention, and

FIGURE 8 is a diagrammatic fragmentary plan view of the vehicle of Figure 7.

Referring first to Figure 1, a variable speed drive transmission 10 is provided to connect a prime mover, such as a diesel engine 11 of a vehicle such as a passenger car, to driving wheels thereof by a drive shaft 12.

The transmission 10 has a first drive member 13 which comprises an input member adapted to be driven by the prime mover 11 whilst the drive shaft 12 comprises a second drive member of the transmission which acts as an output member.

The first drive member 13 is connected to a planet carrier 14 of a first differential gear 15. The planet carrier 14 acts as a first element of the transmission 10 and carries a plurality of planet gears 16 in conventional manner. The planet gears 16 mesh with an annulus gear 17 which acts as a second element of the differential gear 15 and with a sun gear 18 which acts as a third element of the first differential 15.

The annulus 17 is carried by a shaft 19 which extends longitudinally of the transmission and which also carries a carrier 20 of a second differential gear 21 of the transmission.

The carrier 20 carries a plurality of planet gears 22 in conventional manner and acts as a first element of the second differential gear 21.

The planet gears 22 mesh with an annulus 23 which acts as a second element of the second differential gear 21 and with a sun gear 24 which acts as a third element of the differential gear 21.

The two sun gears 18, 24 of the first and second differential gears are non-rotatably connected together by a hollow shaft 25 which is mounted for rotation around the shaft 19.

It will be seen therefore that the third elements of the first and second differential gears are non-rotatably connected together whilst the second element 17 of the first differential gear 15 is non-rotatably connected to the first element 20 of the second differential gear 21.

The shaft 25 which carries the sun gears 18, 24 carries a first pinion gear 27 which meshes with a gear 28 provided on an input element 29 of a continuously variable transmission 30 which, in the present example, is a finite continuously variable transmission (FVT) which in the present example comprises a mechanical transmission having an output element 31 which for a given direction of rotation of the input element 29 can rotate only in a single direction, nor can it provide an output speed close to zero.

The FVT 30 is of conventional type comprising a pair of split pulleys 32, 33 having variably separable cheeks 34 which together define a recess of truncated triangular shape in cross-section and variable width in which a continuous loop member 35 is drivingly received.

By varying the spacing between the cheeks 34 with piston and cylinder adjustors 36, the radius of which the belt 35 engages the pulleys 32, 33 can be varied thereby varying the ratio of the speed of rotation of the output pulley 33 to the speed of rotation of the input pulley 32.

It is preferred that the loop 35 is a metal, such as steel, pusher belt.

The mechanical continuously variable transmission FVT 30 may be of other kind such as a toroidal disc drive comprising two discs each with a toroidal working surface engaged by a roller, the axis of rotation of the roller being adjustable to vary the radial positions of which the roller engages the toroidal surfaces thereby to adjust the relative rates of rotation of the two discs.

All such mechanical continuously variable transmissions have a finite ratio, ρ, of input speed to output speed since the output speed can never reach zero.

The output element 31 of the FVT 30 is connected to a gear 40 which meshes with a gear 41 carried by the hereinbefore mentioned shaft 19.

The output element 31 is releasably connected to the second drive member 12 by a clutch 42.

The second drive member 12 is releasably connectable by a clutch 43 to a gear 44 which meshes with a gear 45 carried by a shaft 46 which carries the annulus 23 of the second differential gear 21.

The second drive member 12 is also releasably connectable by a clutch 47 to a gear 48 which meshes with a gear 49 fixed to the hollow shaft 25.

The clutch 43 provides a first, low speed range, the clutch 47 a second, intermediate speed range, and the clutch 42 a third, high speed range.

The transmission illustrated in Figure 1 has the parameters set out in Table 1 and provides the characteristics illustrated in Figure 1a. The configuration of the transmission is such that at the range change points the components on opposite sides of all the clutches are rotating at the same speed and thus range change can take place without interrupting the drive and during range change the respective two clutches may be simultaneously engaged.

Referring now to Figure 2 there is shown a drive transmission similar to that shown in Figure 1 but provided with four ranges and suitable for use in a lorry. The same reference numerals have been used in Figure 2 to refer to corresponding parts as were used in Figure 1.

The transmission of Figure 2 differs from that of Figure 1 by the provision of a further clutch 50 releasably to connect a gear 51 to the second drive member 12, the gear 51 being in mesh with the gear 27 fixed to the hollow shaft 25. In addition a further set of gears 40a, 41a are provided through which drive is transmitted from output element 31 to the drive member 12.

In this embodiment, the clutch 43 provides a first low range, the clutch 47 a second range, the clutch 42 a third range and the clutch 51 a fourth, highest range.

The transmission shown in Figure 2 has the parameters set out in Table 2 and provides the characteristics shown in Figure 2a.

It will be noted from Tables 1 and 2 that Ro of the second differential 21 is 2 in each case and hence is equal to $\rho = >1$, hence the second drive member 12 may rotate in reverse as well as in forward for a constant direction of rotation of the first drive member 13.

Referring now to Figure 3 there is shown an alternative embodiment of drive transmission having four ranges particularly suitable for use in a back hoe

type excavator where it is desired to have the same speeds available in reverse as forward.

The same reference numerals have been used in Figure 3 to refer to the same parts as were used in Figures 1 and 2.

The transmission of Figure 3 differs from that of Figure 1 by virtue of providing the second drive member 12 with a fourth clutch 53 at one end of the shaft 12 releasably to connect a gear 54 to the shaft 12. The gear 54 meshes with the gear 27 which also meshes with input gear 28 of the FVT 30.

In addition, the second drive member 12 is provided with two further clutches 55, 56 which comprise forward and reverse clutches respectively. The forward clutch 55 can releasably connect a gear 58 to the shaft 12, the gear 58 being in mesh with a gear 59 fixed to a further shaft 60 of the transmission. In addition a further set of gears 40a, 41a are provided through which drive is transmitted from output element 31 to the drive shaft 12.

The reverse clutch 56 can releasably connect a gear 61 to the shaft 12, the gear 61 being in mesh with an idler gear 62 which meshes with a gear 63 fixed to the shaft 60.

While the clutch 55 is engaged and the clutch 56 disengaged, the shaft 60 is rotated in a forward direction in a respective one of the four available ranges provided by the clutches 43 in increasing order of speed.

When it is desired to rotate the further shaft 60 in reverse, the clutch 55 is disengaged and the clutch 56 engaged so that the shaft 60 is rotated in reverse by the shaft 12 at the appropriate speed range by the clutches 43, 47, 53 and 42 in increasing order of speed respectively.

The shaft 60 is rotated by the clutches 55, 56 and associated gears at the same speed in forward as in reverse.

The transmission illustrated in Figure 3 has the parameters set out in Table 3 and provides the characteristics as shown in Figure 3a.

Referring now to Figure 4, there is illustrated another transmission embodying the invention, this transmission having five ranges and is particularly

suitable for use in a tractor where again a wide range of speed is required in reverse.

The transmission is essentially the same as the transmission shown in Figure 1 and the same reference numerals have been used in Figure 4 as were used in Figure 1 to refer to corresponding parts.

The transmission of Figure 4 differs from that of Figure 1 by virtue of being provided with a fourth clutch 70 which can releasably connect a gear 71 to the second drive member 12. The gear 71 meshes with a gear 72 fixed to the hollow shaft 25.

In addition, a further set of gears 40a, 41a are provided through which drive is transmitted from the shaft 31 to the drive shaft 12. The gear 41a is connectable to the shaft 19 by a further clutch 42a.

The drive member 12 is also provided with two further clutches 76, 77 which comprise forward and reverse clutches respectively. The clutch 76 can releasably connect a gear 78 to the drive member 12, the gear 78 being in mesh with a gear 79 fixed to a further shaft 80 of the drive transmission.

The clutch 77 can releasably connect a gear 81 to the drive member 12. the gear 81 meshes with an idler gear 82 which meshes with a gear 83 fixed to the shaft 80 to provide for reverse direction of the shaft 80 compared with the direction in which it is rotated by the drive member 12 when the clutch 76 is engaged and at the same speed.

The clutches 43, 47, 42a, 70 and 42 provide five speed ranges in increasing order of speed, the shaft 80 being rotated in a forwards direction when the clutch 76 is engaged and in a reverse direction when the clutch 77 is engaged.

Of course, the clutches 76 and 77 are never engaged at the same time.

The transmission illustrated in Figure 4 has the parameters set out in Table 4 and provides the characteristics shown in Figure 4a.

It will be noted from Tables 3 & 4 that R_o of the second differential 21 is 3 in each case and hence is equal to ρ -1, hence the second drive member 12 may have a zero speed of rotation but cannot rotate in reverse, for a constant direction of rotation of the first drive member 13.

Referring now to Figure 5, the same reference numerals have been used in Figure 5 as were used in Figure 1 to refer to corresponding parts.

In Figure 5 there is shown a drive transmission similar to that shown in Figure 1 but provided with an FVT 30' of the toroidal disc drive type comprising a pair of relatively rotatable members which are generally disc shaped and are provided with a pair of part-toroidal working surfaces with a rotatable element, generally referred to as a roller, disposed between and in rolling and driving engagement with the surfaces to transmit drive between the members. The axis of rotation of the roller is adjustable to vary the radial positions of which the roller engages the part-toroidal surfaces and hence permit continuous variation of the ratio between the members.

If desired, more than two members having associated working surfaces engaged with a roller may be provided and each pair of working surfaces may have more than one roller engaged therewith.

One member 32' of the FVT 30' is connected to a shaft 29 and the or each other member 33' is provided with a gear 33'a which meshes with a gear 100 which is fixed to rotate with the shaft 19.

The gear 100 meshes with a further gear 101 fixed to a shaft 31. In other respects the structural features of the transmission are as described in connection with Figure 1 as is its method of functioning although the specific parameters of Figure 5 are as set out in Table 5.

Referring now to Figure 6, where, again, the same reference numerals have been used in Figure 6 to refer to the same parts as were used in Figure 1.

A toroidal type transmission 30' similar to that shown in Figure 5 is connected to the shaft 19 and to the shaft 31 by gears 100, 101 as described in connection with Figure 5.

The embodiment of Figure 6 also differs from that of Figure 1 by virtue of the clutch layout where it will be seen that a gear 49, essentially corresponding to the gear 49 of the embodiment of Figure 1, meshes with a gear 48 essentially corresponding to the gear 48 of Figure 1. The gear 45 meshes with a gear 44 essentially corresponding with the gear 44 of the embodiment of Figure 1.

The gear 44 can be connected to a shaft 12 by a clutch C_1 and the shaft 12 can be connected to a gear 102 by a clutch C_r. The gear 48 can be connected to the shaft 12 by a clutch C_r or to the gear 102 by a clutch C_{2r}.

The shaft 12 can be connected to a gear 103 by a clutch C_f. The gear 103 meshes with a gear 104 carried on an output shaft 105. The gear 102 meshes with a reverse idler gear 106 which meshes with a gear 107 fixed to the shaft 105.

It will be noted from Tables 5 and 6 that Ro of the second differential 21 is 2.1 in each case and hence is equal to $\rho = > 1$, hence the second drive member 12 may rotate in reverse as well as in forward for a constant direction of rotation of the first drive member 13.

In other respects the transmission shown in Figure 6 is as described hereinbefore in connection with Figure 1 in structural and functional terms except for the specific parameters which are set out in Table 6.

In all embodiments of the invention the respective range clutches are synchronous on opposite sides thereof at the range change points so that range can be changed without interruption of power transmission as described hereinbefore in connection with the first embodiment.

Although both differentials described above comprise "parallel axis epicyclic gear sets" if desired in any other suitable differential or combination of differentials may be used. Such suitable gear sets may be selected from those described in our applications nos. PCT/GB93/02073 and PCT/GB93/02209.

A transmission as described hereinbefore may be of any desired application but may be used in a construction vehicle of the kind having a moving implement especially the transmission described with reference to Figures 3 to 3b. One such vehicle is illustrated in Figures 7 and 8 where a vehicle 1001 is provided with a front end loader 1002 and a back hoe excavator 1003, both of conventional kind. The front end loader 1002 comprises a bucket 1003 pivotally mounted on a pair of spaced parallel lift arms 1004 which are pivotally mounted on the vehicle for raising and lowering movement by hydraulic rams 1005. In addition, the arms are provided with a pair of crowd rams 1006 for causing crowd movement of the

bucket 1003 about its pivotal connection to the arms 1004 via a crowd linkage 1007.

The back hoe excavator 1003 comprises a bucket 1008 pivotally connected to a dipper arm 1009 and movable for crowd movement relative thereto by a crowd ram 1010 and crowd linkage 1011. The dipper arm 1009 is pivotally mounted at the upper end of a boom 1012 under the control of a dipper arm ram 1013, the boom itself being movable up and down by a raising and lowering ram 1014. The boom 1012 is also pivotal about a vertical axis and can also be slid transversely of the rear of the tractor.

The vehicle 1001 has an engine 1014 which provides motive power for the vehicle and also pressurises hydraulic fluid for operation of the front end loader and back hoe excavator. In addition the vehicle has four ground engageable wheels 1015.

The wheels 1015 are driven from the engine 1014 by a transmission T which is as described in any of the previous embodiments, the input member of the transmission T being driven from the engine 1014 via a shaft 1016 and a rear output member of the transmission being connected to a rear drive shaft 1017 which is connected via a differential 1018 and drive shafts 1019 to the rear wheels of the vehicle. A forward output member is connected via a shaft 1020 to drive the front wheels via a differential 1021 and drive shafts 1022.

If desired, only the rear wheels of the vehicle may be driven, in which case the forward drive member and associated shaft 1020, differential 1021 and drive shafts 1022 may be omitted.

TABLE 1

No. of Ranges 3 % Reverse 6.25	Ro (diff.15) = 2 Ro (diff 21) = 2 Finite FVT Ratio ρ = 4 First Range Recirc. Power P_R = 10%

Example at 5000 RPM Prime mover speed and 200 km/h top speed	
Range	1 2 3
Output RPM	- .625 to 2500 to 5000 to 10000 RPM
Vehicle Speed	- 12.5 to 50 to 100 to 200 km/hr
Max. Power in FVT - 66%	

DRAWBAR PULL

7340 N at - 12.5 to 50 km/h
= 382 Nm on output
= 80 Nm on FVT (small pulley) in first range
= 64 Nm on FVT other ranges.

ENGINE

SPEED 5000 RPM. POWER 100 kw. TORQUE 191 Nm.

DRIVING SHAFT/GEAR	"OUTPUT" SHAFT 12 SPEED RANGE RPM
29	5000 to 10000
44	625 to 2500
48	2500 to 5000
31	5000 to 10000

GEARS	RATIO
48.49	1:2
44:45	1:2
41:40	1:2
28:27	1:2

TABLE 2

No. of Ranges % Reverse (Lorry)	4 3.12	Ro (diff.15) = 2 Ro (diff 21) = 2 Finite FVT Ratio ρ = 4 First Range Recirc. Power P_R = 10%

Example at 2500 RPM Prime mover speed and 120 km/h top speed									
Range		1		2		3		4	
Output RPM	- 312	to	1250	to	2500	to	5000	to	10000 RPM
Vehicle Speed	- 3.75	to	15	to	30	to	60	to	120 km/hr
Max. Power in FVT - 66%									

DRAWBAR PULL

6 ton at - 3.75 to 15 km/h = 1912 Nm on output
= 200 Nm on FVT (small pulley) in first range
= 159 Nm on FVT other ranges.

ENGINE

SPEED 2500 RPM. POWER 250 kw. TORQUE 956 Nm.

DRIVING SHAFT/GEAR	"OUTPUT" SHAFT 12 SPEED RANGE RPM
29	5000 to 10,000
31	5000 to 10,000
44	- 312 to 1250
48	1250 to 2500
40a	2500 to 5000
51	5000 to 10,000

GEARS	RATIO
48:49	1:2
44:45	1:2
41:40	1:4
41a:40a	1:2
27:28	1:2
27:51	1:2

TABLE 3

No. of Ranges % Reverse (Back hoe)	4 100	Ro (diff.15) = 2 Ro (diff 21) = 3 Finite FVT Ratio ρ = 4 First Range Recirc. Power P_R = - %

Example at 2200 RPM Prime mover speed and 50 km/h top speed	
Range	1 2 3 4
Output RPM	0 to 1100 to 2200 to 4400 to 8800 RPM
Vehicle Speed	0 to 6.25 to 12.5 to 25 to 50 km/hr
Max. Power in FVT - 66%	

DRAWBAR PULL

7.6 ton at - 3.125 to + 3.125 km/h
= 1128 Nm on output at 550 RPM
= 94 Nm on FVT (small pulley) in first range
= 47 Nm other ranges.

ENGINE

SPEED 2200 RPM. POWER 65 kw. TORQUE .282 Nm.

DRIVING SHAFT/GEAR	"OUTPUT" SHAFT 12 or 60 SPEED RANGE RPM ±
29	4400 to 8800
31	4400 to 8800
44	0 to 1100
48	1100 to 2200
40a	2700 to 4400
54	4400 to 8800

GEARS	RATIO
48:49	1:2
44:45	1:2
41:40	1:4
41a:40a	1:2
27:28	1:2
27:54	1:2

TABLE 4

No. of Ranges % Reverse (Tractor)	5 100	Ro (diff.15) = 2 Ro (diff 21) = 3 Finite FVT Ratio ρ = 4 First Range Recirc. Power P_R = - %

Example at 2500 RPM Prime mover speed and 80 km/h top speed	
Range	1 2 3 4 5
Output RPM	0 to 625 to 1250 to 2500 to 5000 to 10,000 RPM
Vehicle Speed	0 to 5 to 10 to 20 to 40 to 80 km/hr
Max. Power in FVT - 66%	

DRAWBAR PULL

11 ton at - 5 to + 5 km/h = 2292 Nm on output at 625 RPM
= 95 Nm on FVT (small pulley) in first range
= 95 Nm other ranges.

ENGINE

SPEED 2500 RPM. POWER 150 kw. TORQUE 573 Nm.

DRIVING SHAFT/GEAR	"OUTPUT" SHAFT SPEED RANGE RPM ±
29	-5000 to 10000
31	5000 to 10000
44	0 to 625
48	625 to 1250
40a	1250 to 2500
71	2500 to 5000

GEARS	RATIO
48:49	1:4
44:45	1:4
41:40	1:4
41a:40a	1:1
27:28	1:2
71:72	1:1

TABLE 5

No. of Ranges 3 % Reverse 8	Example Ro (diff.15) = 2.5 Ro (diff 21) = 2 Finite FVT Ratio ρ = 6.25

Example at 2200 RPM Prime mover speed and 50 km/h top speed	
Range	1 2 3
Output RPM	- 740 to 1232 to 3080 to 7700 RPM
Vehicle Speed	- 4 to 8 to 20 to 50 km/hr

DRAWBAR PULL

7.6 ton at up to ± 3.125 km/h

ENGINE

SPEED 2200 RPM. POWER 65 kw. TORQUE 282 Nm.

DRIVING SHAFT/GEAR	"OUTPUT" SHAFT 12 SPEED RANGE RPM
29	3080 to 7700
44	- 740 to 1232
48	1232 to 3080
31	3080 to 7700
19	880 to 2200

GEARS	RATIO
48:49	1:1.786
44:45	1:1.786
100:101	1:3.5
100:33'	1:3.5
27:28	1:1.4

TABLE 6

No. of Ranges % Reverse	5 60	Example Ro (diff.15) = 2.5 Ro (diff 21) = 2.1 Finite FVT Ratio ρ = 6.25

Example at 2200 RPM Prime mover speed and 50 km/h top speed	
Range	2 REV 1 REV N 1 FOR 2 FOR
Output RPM	-4620 to -1848 to -740 to 1232 to 3080 to 7700 RPM
Vehicle Speed	-25 to -10 to -4 to 8 to 20 to 50 km/hr

DRAWBAR PULL

7.6 ton at up to ± 3.125 km/h

ENGINE

SPEED 2200 RPM. POWER 65 kw. TORQUE 282 Nm.

CLUTCH SEQUENCE

	FOR.	REV.
Range N	C_1+Cf	C_1+Cf
1	C_2+Cf	C_2r
2	C_3+Cf	C_3+Cr

DRIVING SHAFT/GEAR	"OUTPUT" SHAFT SPEED RANGE RPM
29	3080 to 7700
44	- 740 to 1232
48	1232 to 3080 & 1848 to -740
31	3080 to 7700 & -4620 to -1848
19	880 to 2200

GEARS	RATIO
48:49	1:1.786
44:45	1:1.786
100:101	1:3.5
100:33	1:3.5
27:28	1:1.4

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, or a class or group of substances or compositions, as appropriate, may, separately or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS:

1. A drive transmission comprising first and second differential gears with a variable speed transmission, operatively connected between an element of the first differential gear and an element of the second differential gear.

2. A transmission according to claim 1 wherein the first differential gear has a first element connected to a first drive member of the transmission, a second element of the first differential gear is connected to a first element of the second differential gear, a second element of the second differential gear is connected to a second drive member of the transmission, a third element of the first differential gear is connected to a third element of the second differential gear.

3. A transmission according to claim 2 wherein the variable speed transmission is connected between the third element of the first differential gear and the first element of the second differential gear.

4. A transmission according to claim 2 or claim 3 wherein the first, second and third elements of the first differential gear correspond to similar elements of the second differential gear.

5. A transmission according to claim 4 wherein the first element of each differential gear comprises a planet carrier, the second element of each differential gear comprises an annulus or the functional equivalent thereof and the third element of each differential gear comprises a sun gear or the functional equivalent thereof.

6. A transmission according to claim 5 wherein the sun gear of the first differential is connected to the sun gear of the second differential whilst the annulus of the first differential is connected to the carrier of the second

differential and the variable speed transmission is connected between the sun gear of the first differential and the carrier of the second differential gear.

7. A transmission according to any one of claims 2 to 6 wherein the first differential has a ratio of $\sqrt{\rho}$ and/or the second differential has a ratio of ρ - ≥ 1 where ρ is the ratio of the variable speed transmission.

8. A transmission according to any one of claims 2 to 7 wherein the second drive member of the transmission is releasably connectable to a desired one of, the second element of the second transmission, an input element of the variable speed transmission and an output element of the variable speed transmission.

9. A transmission according to claim 8 wherein the input element of the variable speed transmission is releasably connectable to the second drive member of the transmission by a first mechanical gear, i.e. a gear with members that have angular velocities in a fixed proportion.

10. A transmission according to claim 9 wherein the input element of the variable speed transmission is connected to the second drive member of the transmission by said first mechanical gear through an intermediate element which interconnects the third elements of the differentials.

11. A transmission according to any one of claims 8 to 10 wherein the output element of the variable speed transmission is releasably connectable to the second drive member of the transmission by a direct connection, i.e. without any difference in angular velocities of the members on opposite sides of the direct connection or by a further mechanical gear.

12. A transmission according to any one of claims 8 to 11 wherein the input element of the variable speed transmission is also releasably connectable to the second drive member of the transmission by a second mechanical gear.

13. A transmission according to claim 12 when dependent directly or indirectly on claim 9 wherein the second mechanical gear is arranged so that the members thereof have angular velocities in a different fixed proportion to the fixed proportion of the members of the first mechanical gear.

14. A transmission according to claim 12 or claim 13 when dependent directly or indirectly on claim 10 wherein the input element of the variable speed transmission is connectable to the second drive member by said second mechanical gear through the intermediate element.

15. A transmission according to any one of claims 12 to 14 wherein the input element of the variable speed transmission is also releasably connectable to the second drive member of the transmission by a third mechanical gear.

16. A transmission according to claim 15 wherein the third mechanical gear is arranged so that the members thereof have angular velocities in a different fixed proportion to the fixed proportions of the members of the first and second mechanical gears.

17. A transmission according to claim 15 or claim 16 wherein the input element of the variable speed transmission is connectable to the second drive member by said third mechanical gear through the intermediate element.

18. A transmission according to any one of claims 15 to 17 wherein at least one further releasable connection is provided between the input element of the variable speed transmission and the second drive member of the transmission.

19. A transmission according to any one of claims 2 to 18 wherein the transmission is provided with a reverse gear downstream of the second drive member of the transmission.

20. A transmission according to claim 19 wherein the second drive member of the transmission is releasably connectable to a further shaft through a forward clutch or a reverse clutch, the reverse clutch having a reverse gear associated therewith.

21. A transmission according to any one of claims 2 to 20 wherein said releasable connections each comprise a clutch.

22. A transmission according to claim 21 wherein the transmissions are arranged so that at range change the members of a clutch to be released and of a clutch to be engaged are rotating synchronously so that both clutches may be simultaneously engaged during range change to permit of range change without interruption of torque transmitted by the transmission.

23. A transmission according to any one of claims 2 to 22 wherein the first drive member of the transmission is an input member and the second drive member of the transmission is an output member.

24. A transmission according to any one of the preceding claims wherein the variable speed transmission is a finite continuously variable transmission having a single direction of rotation of an output element compared with an input element and the ratio of the speed of rotation of the input element to the output element being finite.

25. A transmission according to claim 24 wherein the finite continuously variable transmission is a mechanically continuously variable transmission.

26. A transmission according to claim 25 where the finite continuously variable transmission comprises a split pulley type having a pair of split pulleys having variable spacing cheeks, drivingly interconnected by a continuous loop and in which the radius at which the loop drivingly engages the split pulleys is

continuously adjustable by varying the spacing between the cheeks of the split pulleys.

27. A transmission according to claim 25 wherein the mechanical continuous variable transmission is of the toroidal disk drive type comprising two disks, each with a toroidal working surface engageable by a roller, the axis of rotation of the roller being adjustable to vary the radial positions at which the roller engages the toroidal surfaces.

28. A transmission according to any one of the preceding claims wherein the first and second differentials each comprise a gear set comprising a planet carrier, acting as a first element, supporting planet gears which are rotatable about axes parallel to the axis of rotation of an annulus, acting as a second element, and in mesh with the annulus and in mesh with a sun gear, acting as a third element.

29. A transmission substantially as hereinbefore described with reference to Figs. 1, 1a, or Figs. 2, 2a, or Figs. 3, 3a, or Figs. 4, 4a, or Fig. 5, or Fig. 6.

30. A transmission according to any one of the preceding claims when provided in a vehicle with the driven member of the transmission being connectable to provide motive power for the vehicle and/or provide a power input to apparatus of the vehicle.

31. A transmission according to claim 30 wherein the vehicle is a construction machine provided with an earth moving appliance.

32. Any novel feature or novel combination of features described herein and/or in the accompanying drawings.

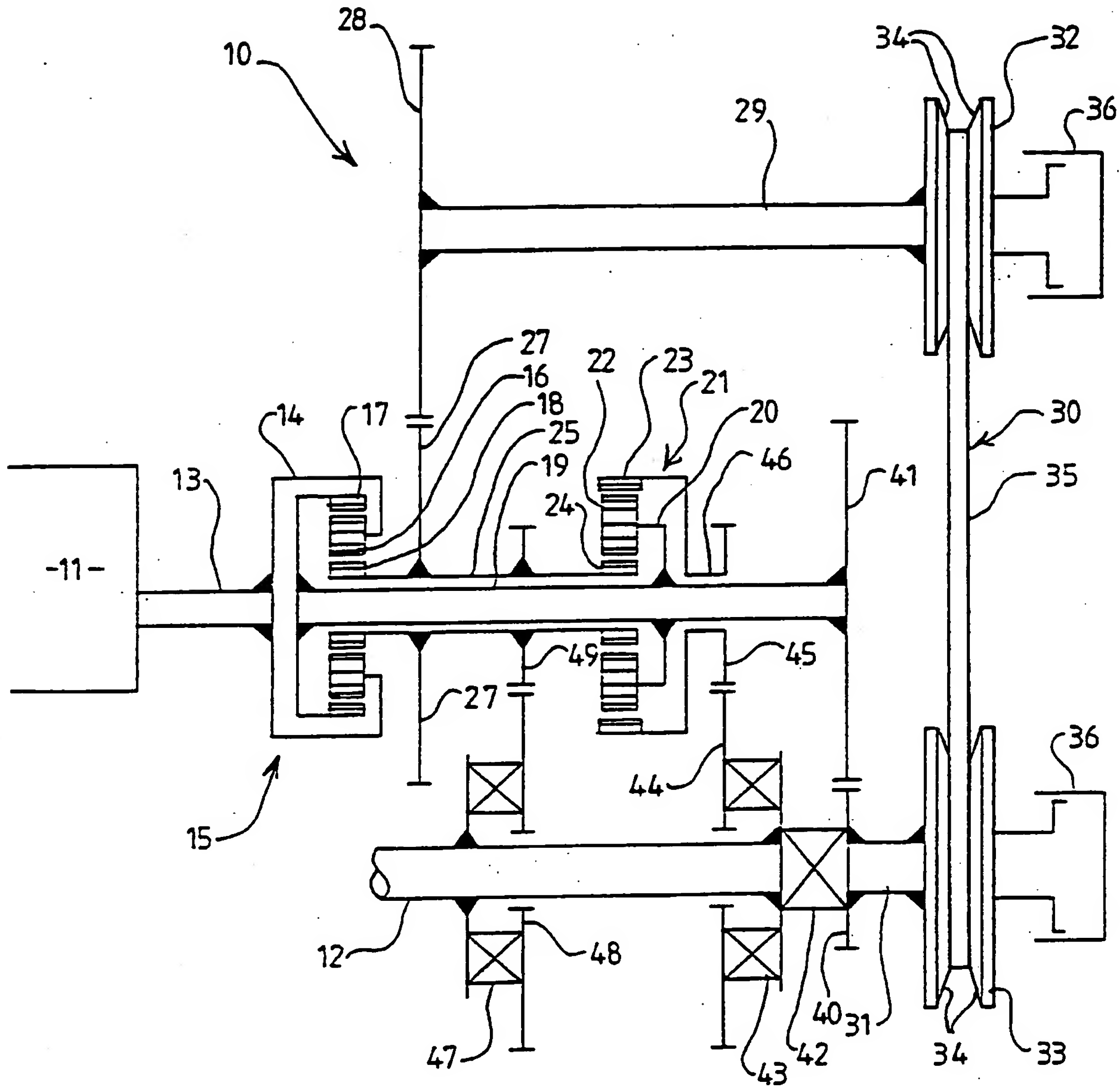
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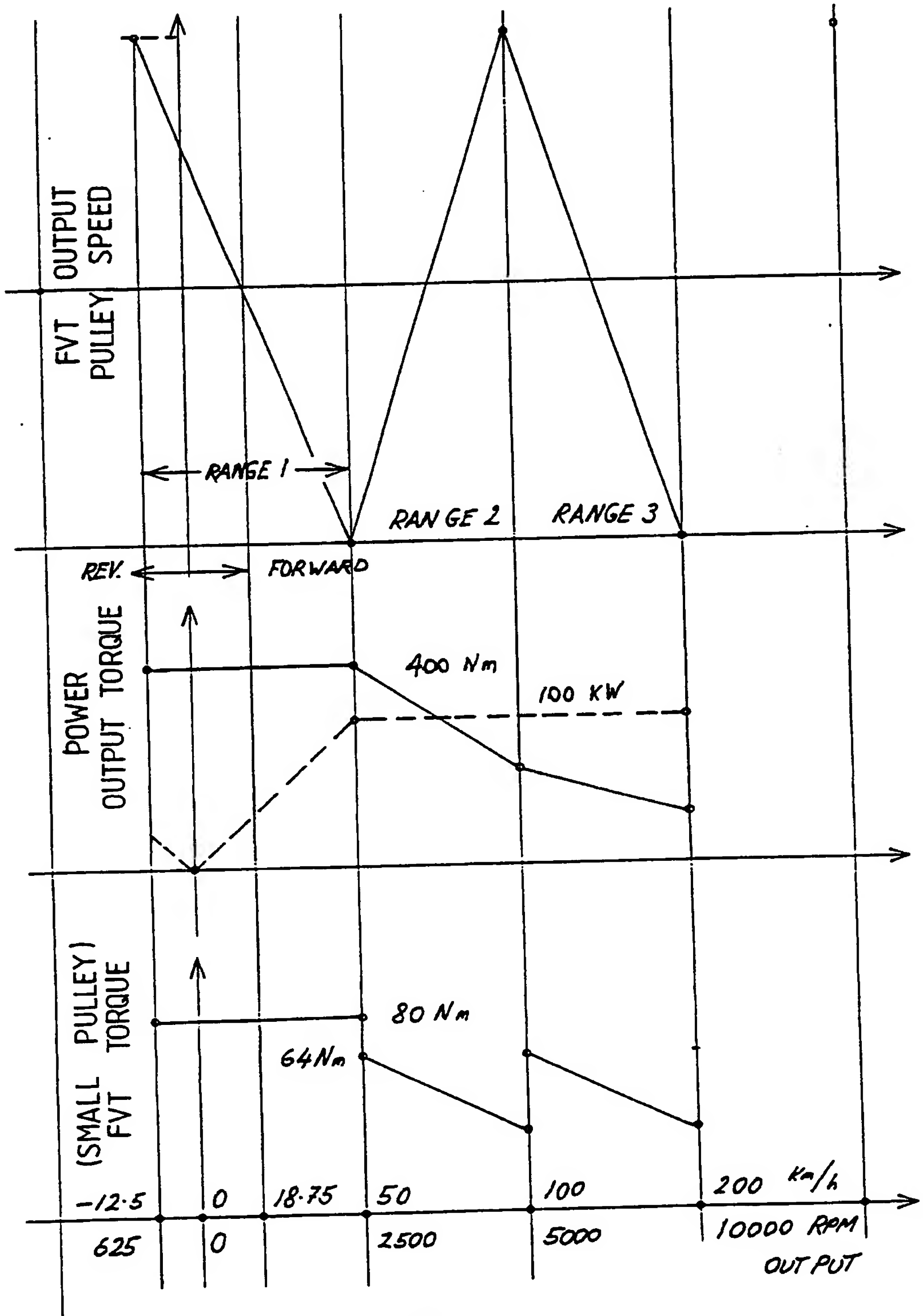
FIG 1



100 KW CAR
INPUT DIFFERENTIAL POWER SPLIT

FIG 1a

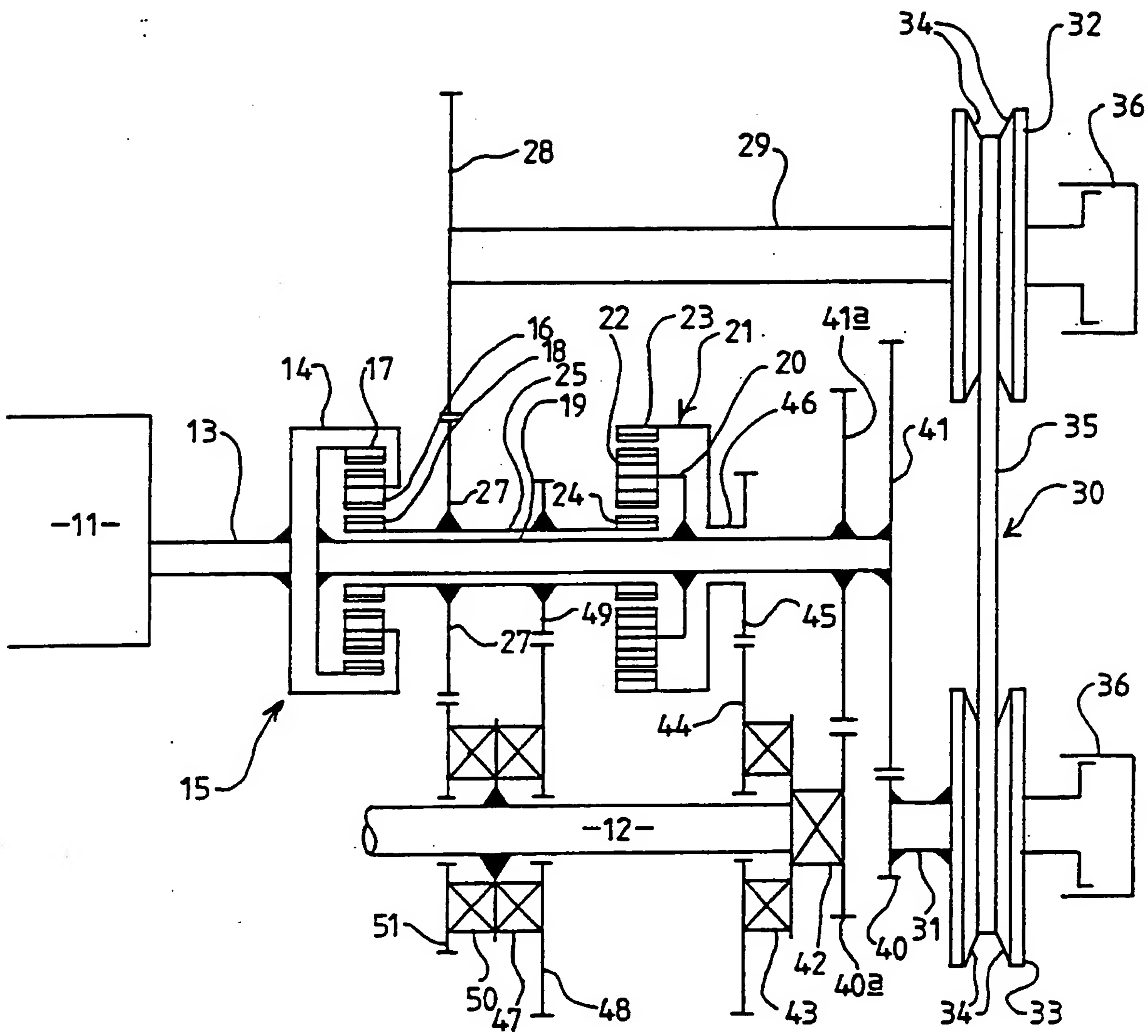

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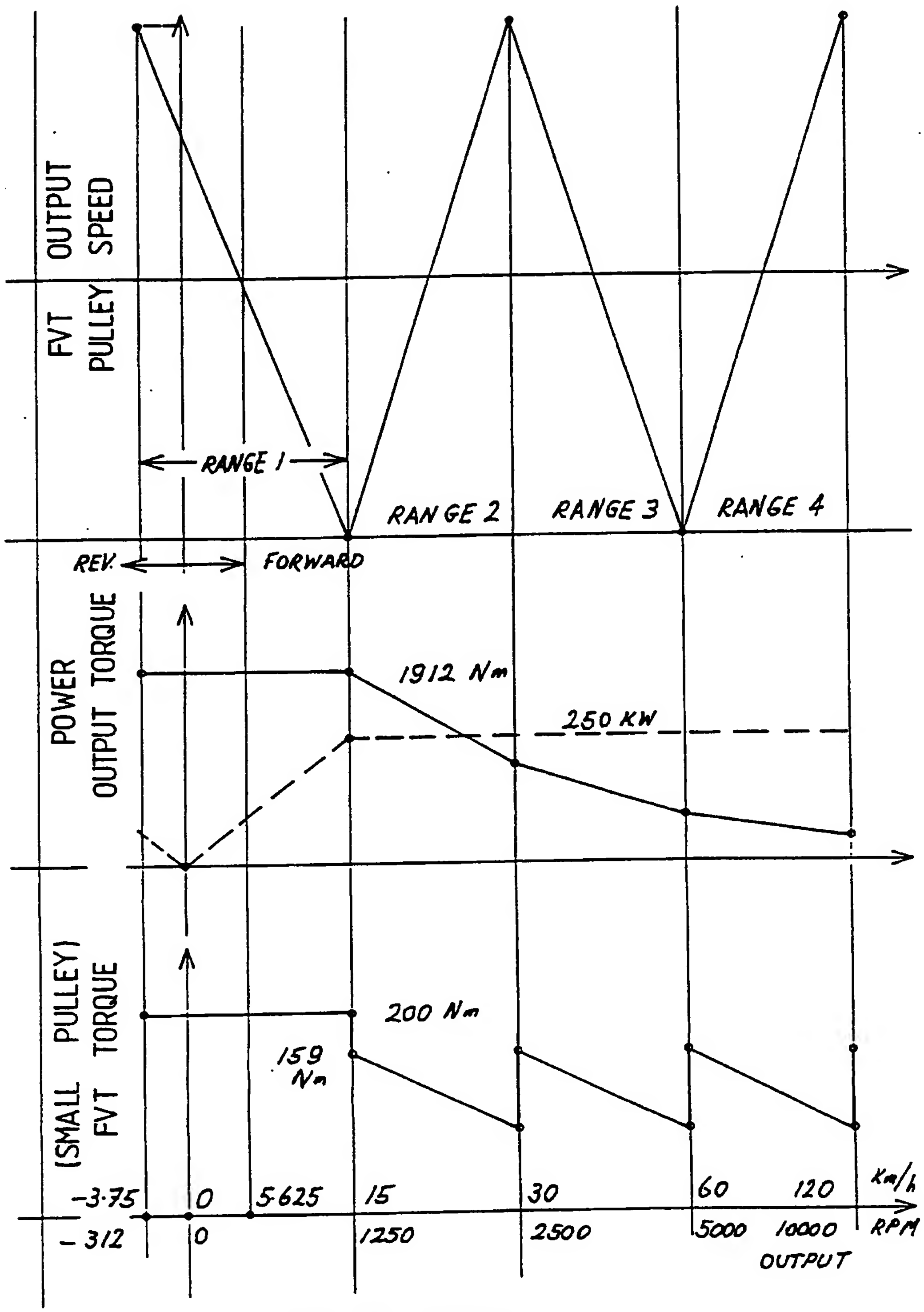
FIG 2



250 KW LORRY
INPUT DIFFERENTIAL POWER SPLIT

FIG 2a

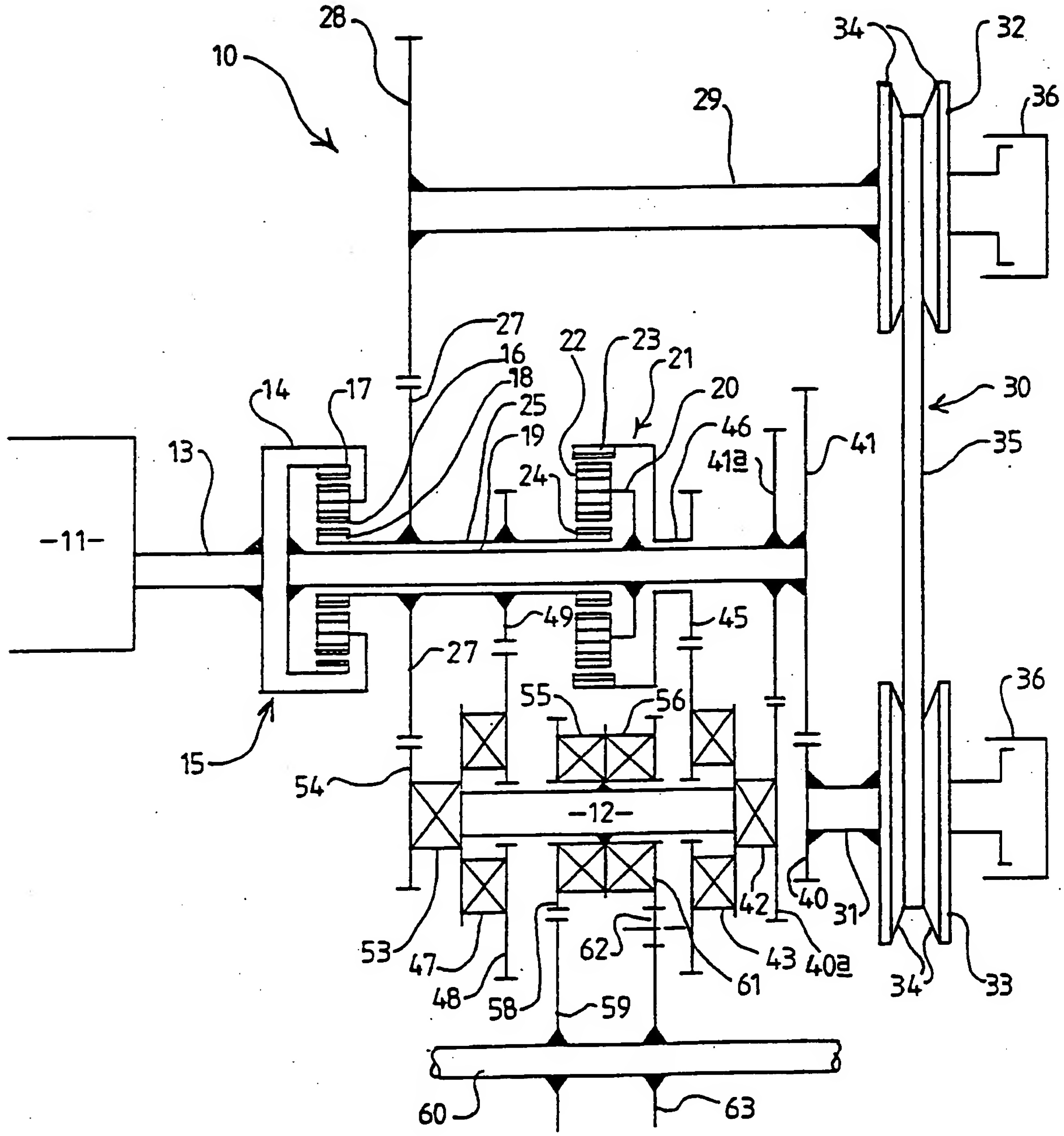

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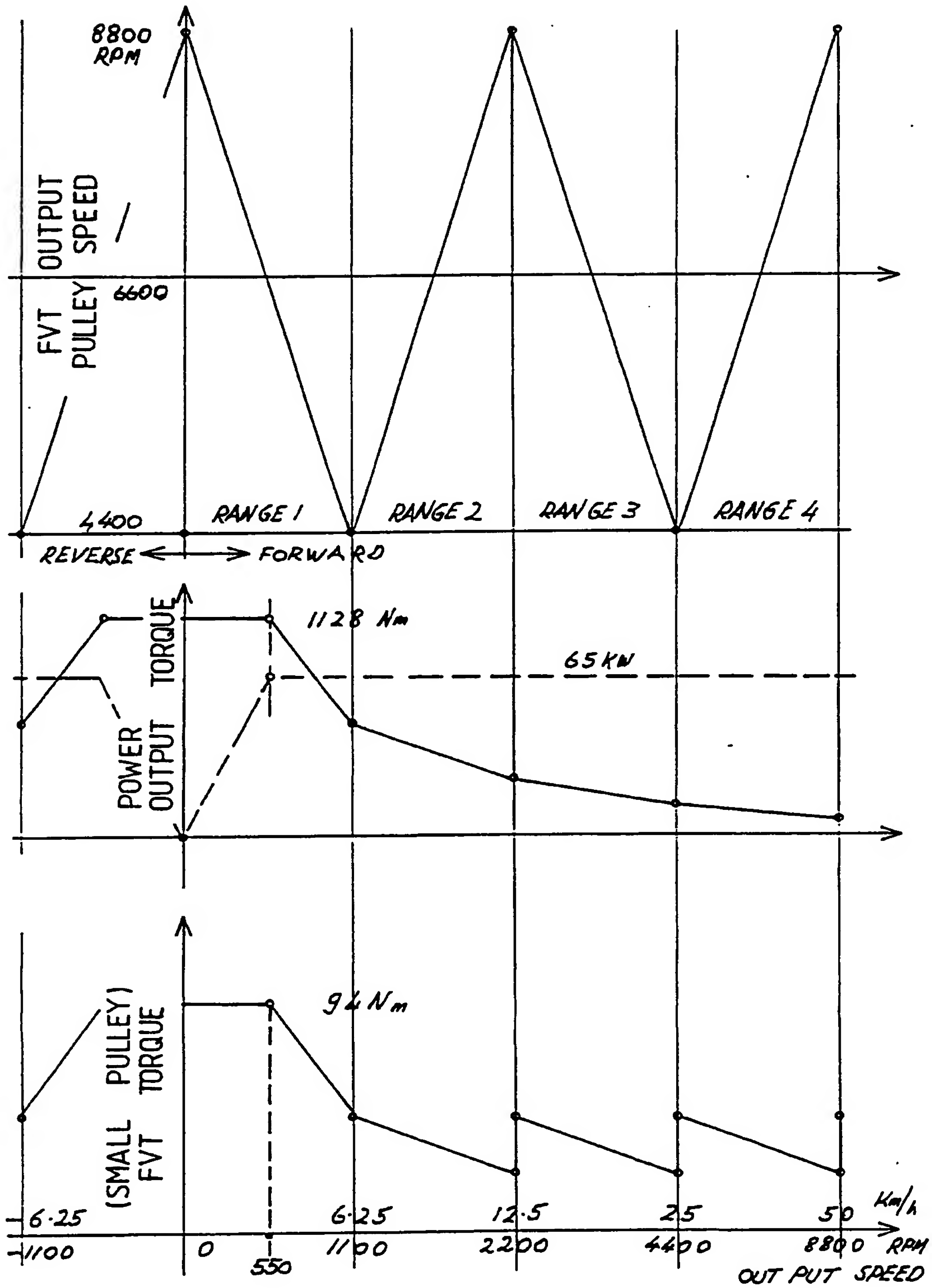
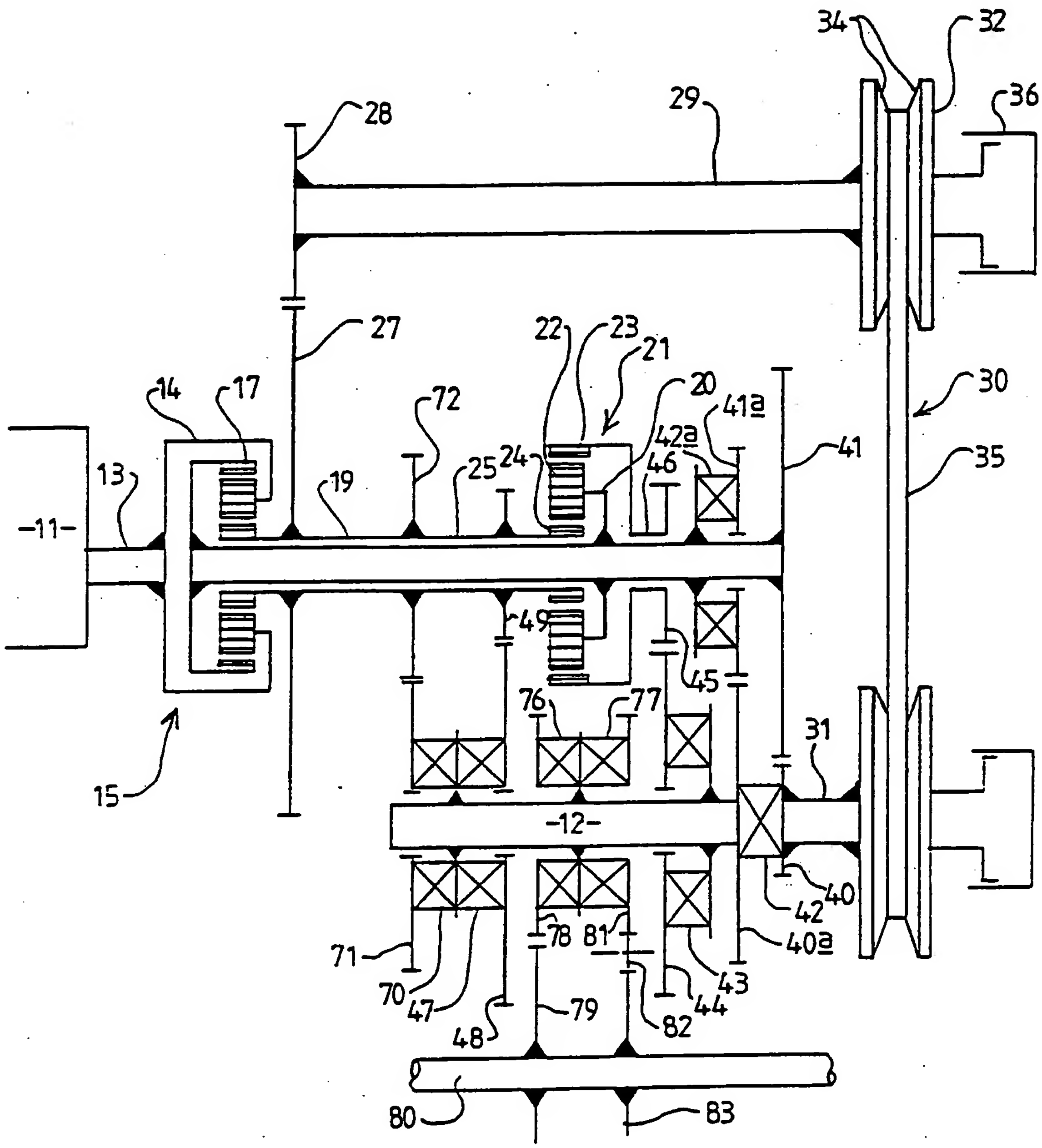
FIG 3



65 KW BACKHOE
INPUT DIFFERENTIAL POWER SPLIT FIG 3a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13
19
-11-
49
45
76
77
31
15
-12-
40
42
40a
71
70
47
78
81
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44
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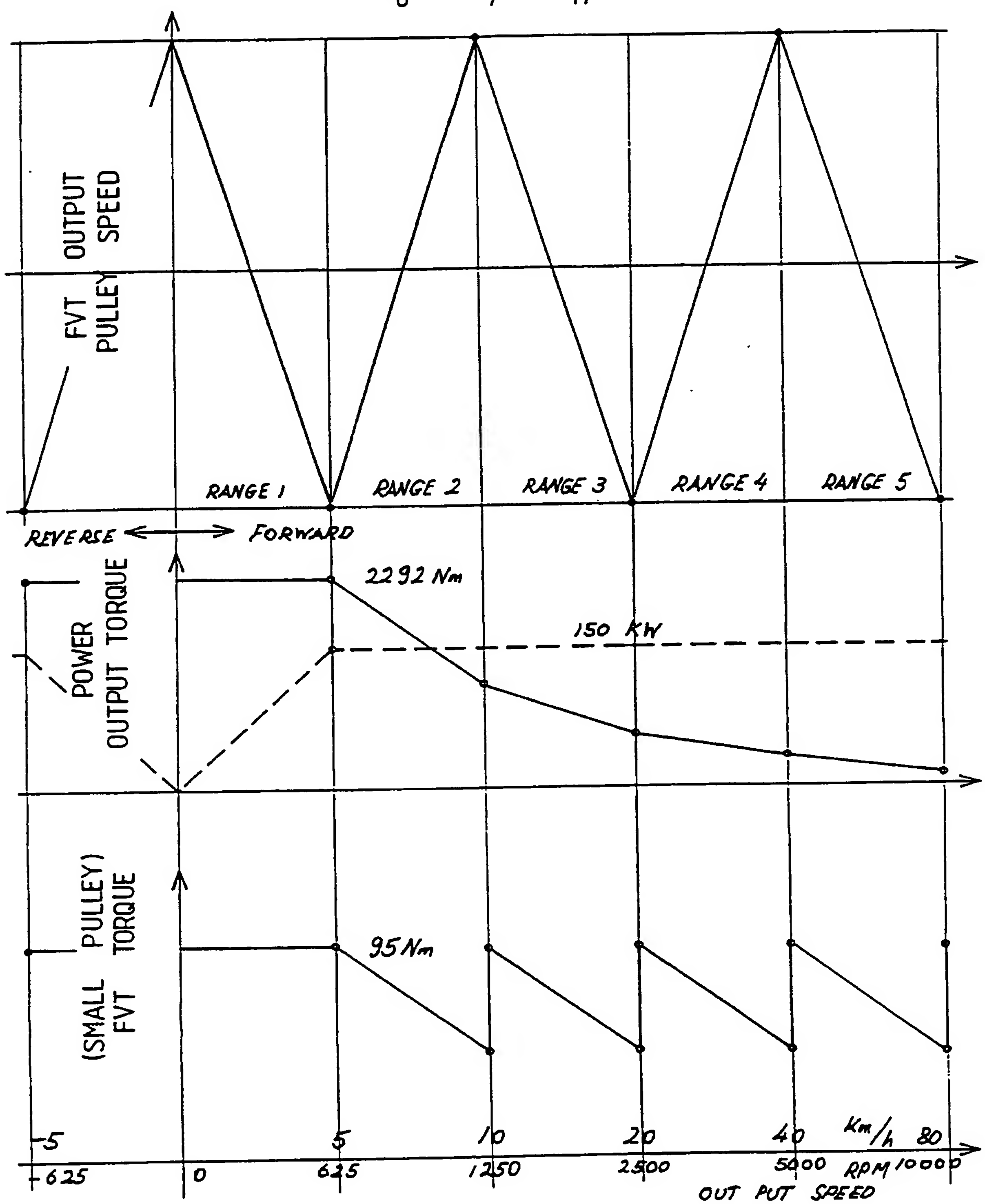
80
83

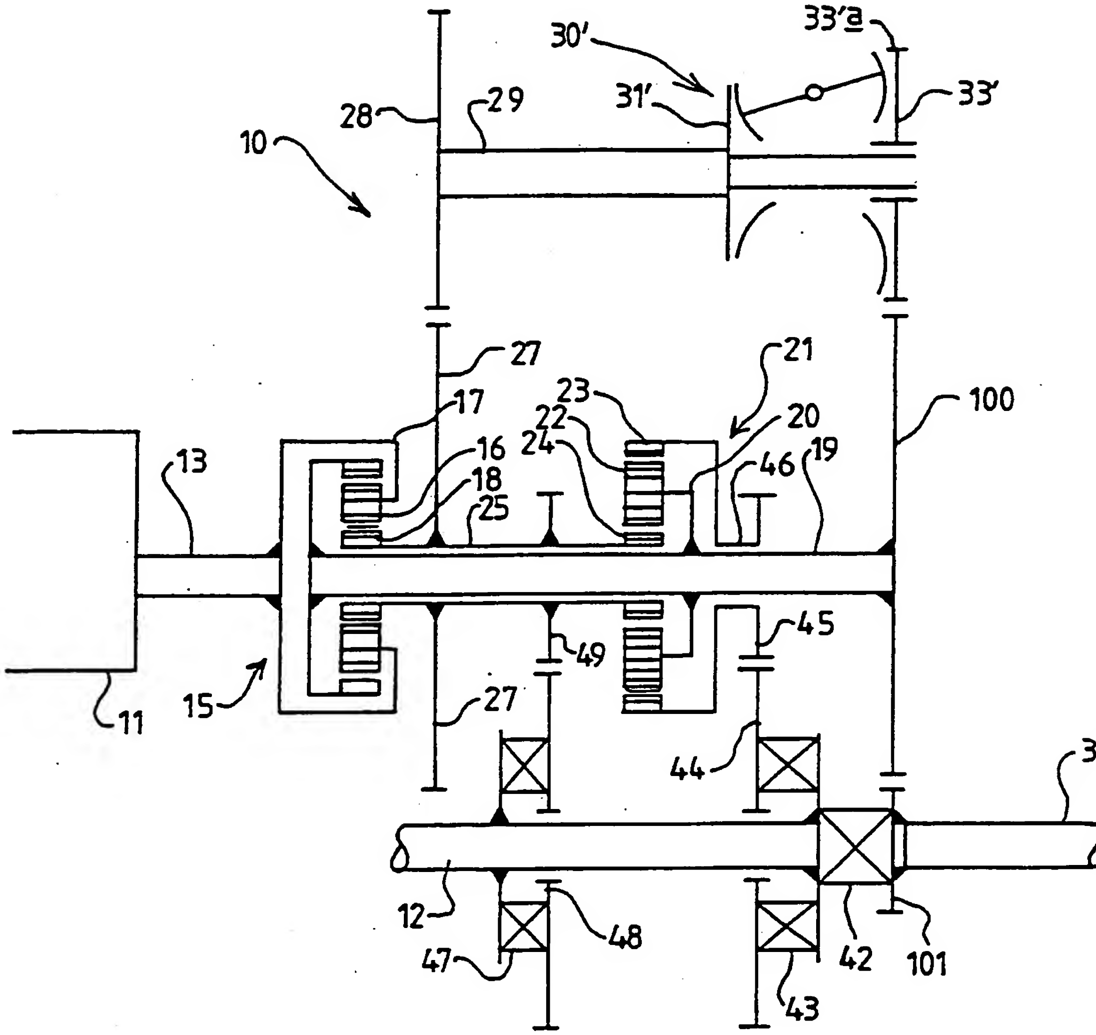
FIG 4



150 KW TRACTOR
INPUT DIFFERENTIAL POWER SPLIT

FIG 4a

SUBSTITUTE SHEET



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31'
33'a
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100
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101
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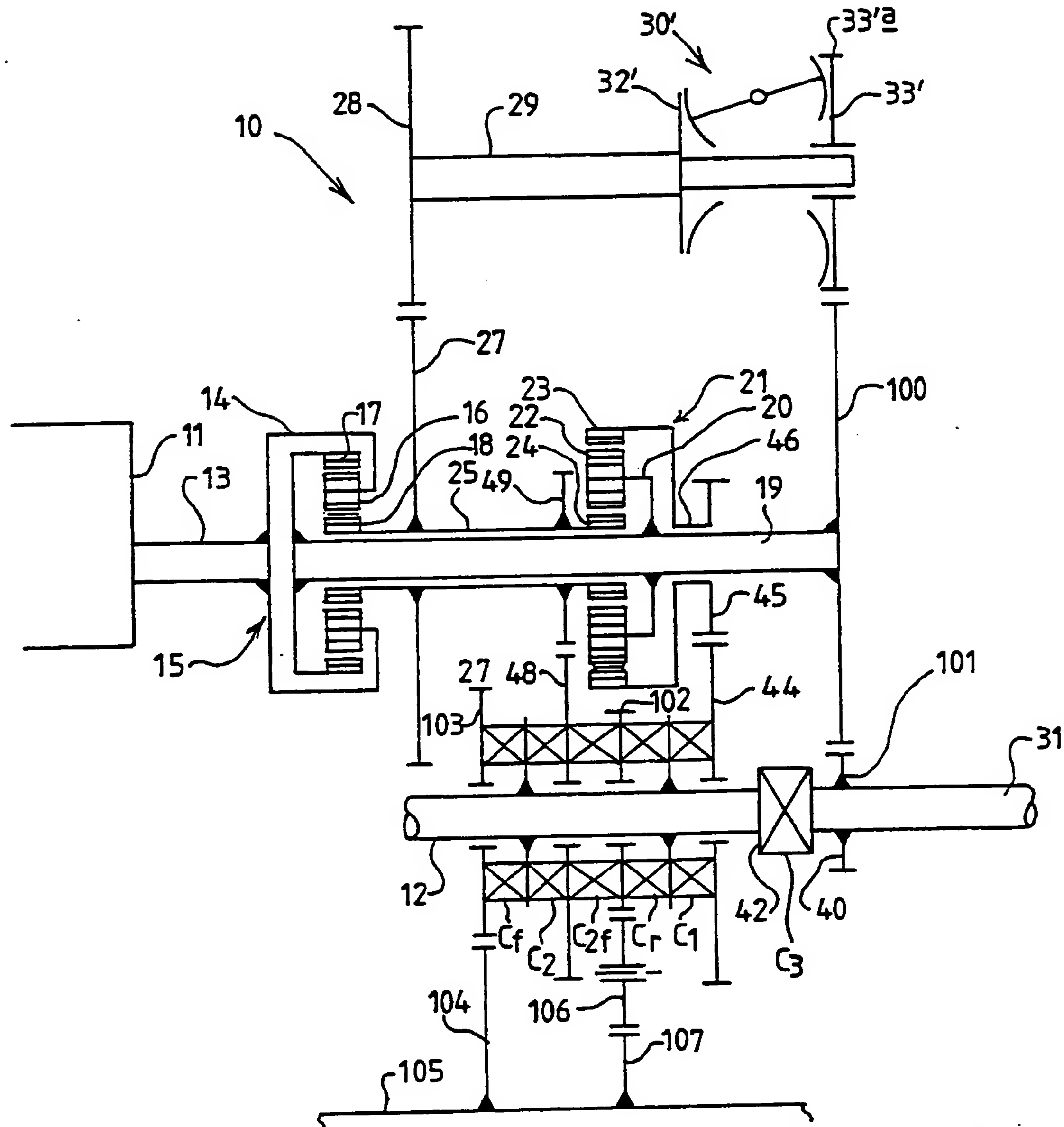
FIG 5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102
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Cf
C2
C2f
Cr
C1
C3
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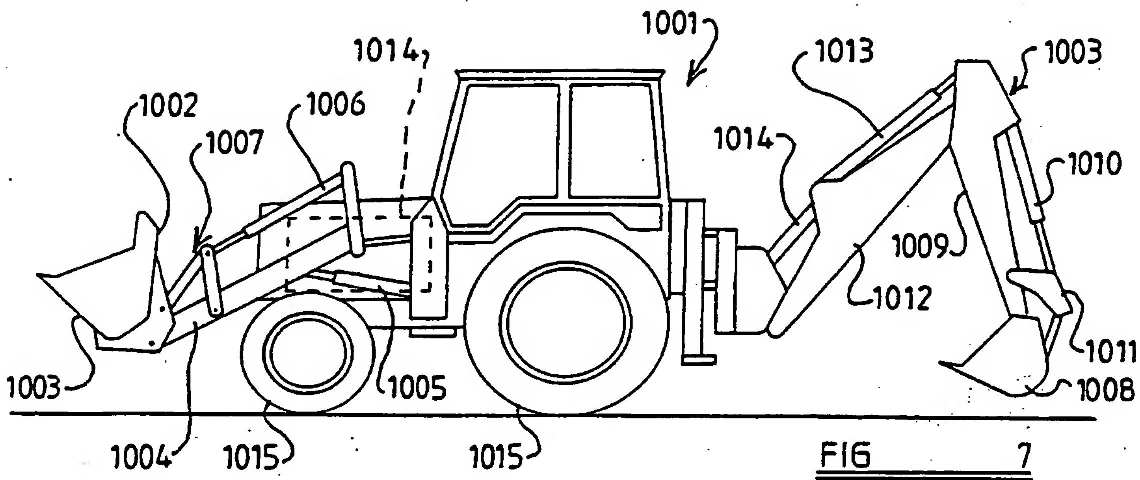
106
107
105

FIG 6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1014
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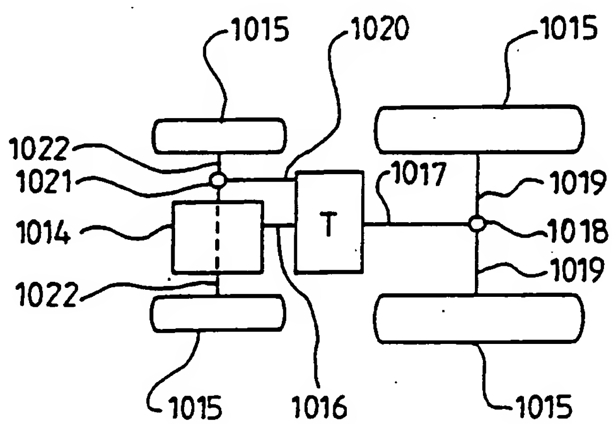
1015

FIG 7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1014
1018
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1022
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1016
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FIG 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 93/02635

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 F16H37/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 F16H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ANTRIEBSTECHNIK vol. 323, no. 7 , 1970 , MAINZ pages 259 - 262 H.J.MORHARD 'FMB-VARIATOREN' see page 261 - page 262; figure 14	1-3,25, 26,28
A		4-6
X	US,A,3 046 814 (SOEHRMAN) 31 July 1962 see column 1 - column 3; figure 1	1-3,25, 26,28
X	EP,A,0 177 241 (LEYLAND) 9 April 1986 see page 4 - page 6; figures 1,2	1,8,22, 25,27,28
X	WO,A,92 03671 (TOROTRAK) 5 March 1992 see page 1 - page 6; figures 1-3	1,9,22, 27,28

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
23 March 1994	18. 04. 94
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Authorized officer Flores, E

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INTERNATIONAL SEARCH REPORT

Interr. al Application No
PCT/GB 93/02635

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE,A,19 44 070 (FERODO) 5 March 1970 see page 11; figure 2 ---	1,18-21, 25,26,28
A	EP,A,0 460 584 (HURTH) 11 December 1991 see page 2; figures 1,2 -----	1,28,30, 31

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern ial Application No
PCT/GB 93/02635

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		US-A-	4768398	06-09-88
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		GB-A-	1250990	27-10-71
		US-A-	3667321	06-06-72
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